SEMI-ANNUAL PROGRESS REPORT
NASA GRANT NAG5-720

16 April 1986 - 15 November 1986

THE GAMMA-RAY SPECTROMETER EXPERIMENT ON THE SOLAR MAXIMUM MISSION SATELLITE

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GREENBELT, MARYLAND 20771

15 February 1987

NASA Grant NAG5-720
SMM GRS - Semi-Annual Status Report
Period 1986, April 16 - 1986 November 15

SUMMARY

In this report we summarize the major activities of the SMM GRS team members at UNH and NRL and the work of Guest Investigators since the last *Semi-Annual Report* through 1986 November 15. In addition, we provide an updated list of published papers and invited papers or contributed papers presented at scientific meetings.

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1.0 GRS INSTRUMENT RESPONSE AND FLIGHT OPERATION

Progress has continued on preparation of a document which describes in detail the GRS instrument response and flight operation. This report, which is near completion, includes a detailed mechanical description of the instrument preflight and inflight calibration data, the most current response functions for the X-ray detector, the main channel spectrometer and the high-energy detector of the SMM GRS. Subsequent supplements for the document will contain off-axis response functions and results from orbital background studies which will be useful for nonsolar studies.

2.0 SOLAR FLARE STUDIES

2.1 GRS DATABASE

Work continues on a GRS flare database. This database will include the measured parameters of all flares detected by the GRS at energies > 300 keV. It will also contain measured fluxes or upper limits in all GRS energy bands using the most current response functions. Whenever possible, time histories and spectral plots for specific flares will be provided. The orbital background used for data reduction, as well as our assessment of data quality, will be included.

2.2 THE ACCELERATION OF ELECTRONS AND IONS IN SOLAR FLARES

Work continues on a study of the acceleration of electrons and ions in the "impulsive" phase of solar flares. The sample studied is comprised of $\sim$ 150 events from the GRS flare list. The study includes the correlation of electron bremsstrahlung and nuclear line emission, and evidence for two populations of flares. The effects due to electron beaming, evidence for an extended emission phase in a few flares, and the observed 155-day periodicity of flare recurrence are being considered in this study.

2.3 GAMMA-RAY LINE SPECTRA IN SOLAR FLARES

A review of γ-ray spectroscopy of solar flares with the SMM GRS has been initiated. The review emphasizes GRS's ability to separate the electron bremsstrahlung continuum from the nuclear broad and narrow line spectra within the impulsive and extended emission phases of flares. It will also

demonstrate the GRS ability to perform nuclear line spectroscopy studies and review the solar abundance studies possible with nuclear line spectrometers.

2.4 VERY ENERGETIC GAMMA RAYS FROM THE 1982 JUNE 3 SOLAR FLARE

Results of a study of very energetic γ-rays from the 1982 June 3 solar flare were presented at the COSPAR meeting by D. Forrest and Co-Authors. The γ-ray Spectrometer on the Solar Maximum Mission (SMM) satellite has recorded high-energy γ-ray and neutron emission from the flare on 1982 June 3. During the 65 s impulsive phase the γ rays > 10 MeV contain emissions from both primary electron bremsstrahlung and nuclear pion decay. Hence the impulsive phase acceleration process must produce both primary electrons with energies > 60 MeV and ions > 500 MeV. This flare also has an extended emission phase lasting more than 1000 s which is most easily observed at γ-ray energies > 10 MeV. After removing the counting rates from the more slowly moving neutrons produced at earlier times, the resulting γ-ray spectrum can be entirely explained by nuclear pion production. We find that more than 70 % of the pions were produced in the extended emission phase. In contrast, more than 70 % of the high-energy primary electron bremsstrahlung and the $<$ 30 MeV ion produced nuclear line emission occurred in the 65 s impulsive phase. This represents the first clear observation of a new acceleration process which produces an electron deficient, very hard ion spectrum extending beyond 1000 MeV. A paper is in preparation on this topic to be submitted to Astrophysical Journal.

2.5 THE PION SPECTRA OBSERVED IN THE IMPULSIVE AND EXTENDED PHASES OF FLARES

The pion spectra observed in the impulsive and extended phases of three flares has been studied further. The SMM GRS has observed clear evidence for the production of neutral pions in both the impulsive and extended phases of solar flares. Within the impulsive phase, the pion spectra is always accompanied by a power-law continuum which must be from primary electron bremsstrahlung. However, during the extended phase there is no clear evidence for emission by primary electrons at energies > 1 MeV and all the photon spectra > 9 MeV appears to be produced by the decay of charged and neutral nuclear pions. Our attempts to fit the observed pion photon spectra require a charged to neutral pion ratio > 10. It is difficult to reconcile this high ratio with the basic nuclear cross-section involved in pion production. Our observation seem to require either:

- The acceleration of mono-energetic electrons to > 10 MeV or,

- The presence of red-shifted and/or scattered neutral pion γ rays.

The first alternative may be easier to accept, however there is other evidence which shows that the second alternative may be correct.

We are attempting to resolve this by a careful comparison of all the emissions observed in these two flares. These emissions include 0.511 MeV, 2.22 MeV, and (4-8) MeV as well as what appears to be a scattered component from each of these nuclear emissions. The second alternative, if confirmed, would require strong beaming of the accelerated ions as well as a spectrum peaked at high energies.

2.6 GRS AND GROUND LEVEL SOLAR NEUTRON OBSERVATION

Extensive work was carried out on completing the analysis of the combined GRS and Jungfraujoch neutron monitor observations of the 1982 June 3 solar flare. The basic results are summarized in the following abstract of the paper "Solar Neutron Emissivity during the large flare on 1982 June 3" to be published in the Astrophysical Journal on July 15, 1987.

ABSTRACT — Observations made with the Gamma-Ray Spectrometer (GRS) on the Solar Maximum Mission (SMM) satellite and with the Jungfraujoch neutron monitor are used to determine the directional solar neutron emissivity spectrum from ~100 MeV to ~2 GeV during the solar flare on 1982 June 3. The experimental data require a time-extended emission of the neutrons at the Sun with the majority of the neutrons produced after the impulsive phase. Fits to the observational data are provided by neutron emissivity spectra with spectral forms $E_n^{-2.4}$, *and* $E_n^{3/8}\exp - (E_n/0.016)^{1/4}$. *The power-law form requires a truncation at energy* E_c *where 2 GeV* $< E_c <$ *4 GeV. In both cases the integrated neutron emissivity for energies > 100 MeV is* $\sim 8 \times 10^{28}$ neutrons sr^{-1}. *These high-energy spectra are in agreement with the neutron spectrum for energies < 100 MeV derived from observations of neutron decay protons. The observations also require that the first GeV protons producing the GeV neutrons interacted at the Sun within a time span of at most 16 s, implying neutron production at densities* $n > 10^{14} cm^{-3}$. *We have also considered the observational effects of high-energy neutron spectral changes throughout this event. The present analysis of the neutron data for* $E_n \geq 100$ *MeV is unable to differentiate between isotropic and nonisotropic emission of the neutrons.*

2.7 THE 154-DAY PERIODICITY

Work continued on a study of the 154-day periodicity in recurrence of energetic solar flares. The occurence frequency and properties of solar flares as observed in soft X-rays, hard X-rays and γ rays have been investigated using the 154-day period first reported by Rieger *et. al.*(1984). The strongest 154-day periodic component is an abrupt increase in the flare probability with a 15-day duration. Hence the time dependent flare probability is most simply represented by a 154-day periodic square-wave with a 10% duty cycle. The ratio of the number of flares within this 10% interval to the total number of flares observed has been compared at several intensity levels for both soft and hard X-ray, and γ ray flares over eight cycles of 154 days each. This ratio is strongly size dependent with a minimum for the smallest soft X-ray flares at $13.9 + 0.3\%$ and a maximum for the largest soft X-ray, hard X-ray and γ-ray flares of $31 \pm 2\%$, $27 \pm 2\%$ and $35 \pm 4\%$ respectively. This observation requires a change in the flare size-frequency distribution within the preferred 15-day interval as compared to the average flare size-frequency distribution. The flare sites producing this periodic hard distribution of flares shows no dependence on Carrington longitude or other obvious local grouping, and therefore seems to be global in nature.

2.8 SMM GRS OBSERVATIONS OF THE SOLAR FLARE CONTINUUM

Work has also continued on an examination of the SMM GRS observations of the solar flare continuum between 300 keV and 1 MeV for evidence of anisotropy in the distribution of radiating electrons. An enhancement has been found in the number of flares detected near the limb and a center-to-limb variation in the spectral indices of flares. Together these results provide strong evidence that the distribution of radiating electrons is anisotropic. To investigate this problem further a series of calculations have been made on the directivity of bremsstrahlung emission from anisotropic energetic electron distributions. These calculations are an important advance beyond previous calculations because they directly include the Compton albedo from the solar atmosphere. For a number of likely electron distributions, Compton albedo was found to play an important role. These calculations were used to develop diagnostics that were very important in establishing observational evidence for the anisotropy of flare electron distribution. An initial draft of a paper on this subject has been prepared. A final manuscript that is ready for submittal to the Astrophysical Journal will be completed in early 1987.

2.9 CALCULATIONS ON THE COMPTON CONTINUUM

The Compton Continuum associated with the neutron capture line is dependent on the depth at which the line is produced. The idea is to use the photospheric photons that are Compton scattered into the continuum as a measure of the line source function in the solar atmosphere. This, in turn, can be used to constrain both the angular and the energy distribution of the energetic parent ions that generate the neutrons which are ultimately captured. One of the main conclusions of this study is that the continuum/line ratio observed in the 1982 June 3 flare is too large to be explained by any of the twelve models discussed in the preprint by Hua and Lingenfelter (1986).

3.0 GRS-SEP CORRELATION

Work continued on a study of solar flare nuclear γ-rays and interplanetary proton events. The objective is to study flares to determine the association of accelerated ions which "escape" from the Sun and are observed at 1 AU with those which are "trapped" on the Sun and produce nuclear γ rays. Specifically, we want to confirm or reject earlier results, based on only a few events, which indicated a poor correlation between these two particle populations. The implication of this poor correlation is either a poorly understood flare "geometry effect" which varies widely from flare-to-flare, or separate acceleration processes for these two particle populations.

4.0 COSMIC GAMMA-RAY STUDIES

4.1 GRS COSMIC GAMMA-RAY BURST LIST

A computerized listing is being prepared of the measured parameters of all cosmic bursts detected by GRS at energies > 300 keV. It will include time histories and spectral plots of all events as well as an orbital background determination. The main objective is to determine measured fluxes and provide an accessible data base for future studies. It will also include SMM spacecraft limitations for each flare such as data qualify and eclipse times.

4.2 SOURCES OF GALACTIC POSITRONS

Theoretical work has been initiated on mechanisms for the formation of diffuse positron emission in the galaxy and the physical constraints observations of Supernovae can place on Supernovae models. No firm conclusions have been reached on these subjects to date.

5.0 SUMMARY OF COMPUTER OPERATIONS FOR THE PERIOD OF MAY TO NOVEMBER 1986

Computer activities, during the period of May to December 1986, were highlighted by the increased usage of the MicroVAX II System which was acquired in March, 1986. This system was initially heavily used for Monte Carlo calculations. The factor of 10 speed increase over our existing Honeywell mini-computer was appreciated immediately for these calculation intensive jobs, while slower tape reading and primary data reduction continued on the Honeywell. Due to the age and high cost of maintenance for the Honeywell system we have converted most of our primary data reduction software from the Honeywell to the MicroVAX and are currently working on converting the other needed programs. During the summer our existing 9-track Pertec tape drives were interfaced to our MicroVAX system to allow the direct reading of IPD data tapes and thus facilitate the move of data reduction and analysis software on to the MicroVAX. To aid in data handling on the MicroVAX system a data manipulation and graphing package, IDL, was put on the system during October as an all-purpose data handling tool.

During the month of August a study was conducted on the feasibility of accessing the entire 6-year SMM data base given the manpower and the limitations of our computer hardware. At the conclusion of the study it was determined that the creation of a Long Term Data Base (LTDB) was possible given all the requirements and limitations that this process was subject to. An additional person was hired to research the commercial data base products which would be at the heart of the LTDB project. While the data base products were being researched, implementation began on the programs to be used in the two step IPD data compression process which is used to reduce the primary data into an acceptable amount of data that can be used by the data base product.

During the *Long Term Data Base* development Monte Carlo modeling and Honeywell-MicroVAX program conversion will continue on the MicroVAX while Solar Flare data reduction activites will continue on the Honeywell system. We are very pleased with the versitlity that the MicroVAX has shown us and we feel that this increased flexibility will allow us to pursue data analysis paths not available to us before.

NAVAL RESEARCH LABORATORY

1.0 SEARCH FOR FLARE-PRECURSOR PROTONS

A search was conducted for evidence of nuclear-line emission prior to the impulsive phase of 8 selected solar flares from 1980 to 1982. No evidence for any statistically significant line emission was found. This places upper limits of $\sim$ 1025 erg s^{-1} on the power in nonthermal protons above 10 MeV in the preflare phase. This work was performed in collaboration with Dr. G. Simnett of the University of Birmingham, England. Results from this study were presented at the Toulouse COSPAR Meeting and will be published in *Advances in Space Research.*

2.0 DIFFUSE GALACTIC ANNIHILATION RADIATION

A 511 keV annihilation line has been detected each December when the GRS's aperture passes near the galactic center. The inferred point source intensity is about 2×10^{-3} g cm^{-2} s^{-1} and varies no more than 30% from year-to-year. Comparison with upper limits obtained from narrow aperture balloon detectors in 1981 and 1984 suggests that flux observed by the GRS is from an extended source. The presence of such an extended source is consistent with all 511 keV measurements from the galactic center region with the exception of the spring 1980 HEAO-3 exposure. A preliminary report of this new detection was presented at the Toulouse COSPAR Meeting and will be published in *Advances in Space Research.* An extended paper for Ap.J. is in preparation. Abstracts on this work have also been submitted to the AAS and Cosmic Ray Conference.

3.0 COSMIC GAMMA-RAY BURSTS

The GRS has observed an intense γ-ray burst over three decades in energy from $\sim$ 20 keV to $\sim$ 100 MeV. This is the largest range in energy for a γ-ray burst detected by any instrument to date. We also find that the overall spectral shape does not appear to change significantly on timescales as short as 2 s. No evidence was found for narrow lines. Preliminary results from this study were presented at the Toulouse COSPAR Meeting and will be published in Advances in Space Research.

This new result is consistent with earlier studies of bursts with the SMM detector. Steve Matz produced a PhD thesis covering this analysis. He found that the original picture of γ-ray bursts as soft, thermal phenomena has been substantially changed by the SMM GRS observations. Most events have detectable high-energy flux, and the GRS data are consistent with emission to

greater that 5 MeV in all bursts. A significant fraction of the total observed burst energy can be in photons with energies greater than 1 MeV. New physical models are needed which can produce hard spectra to 10 MeV and above on short timescales. The GRS data also set upper limits of 10-12 G on magnetic fields at the burst sites, for isotropic emission models.

Additional evidence for hard-to-soft spectral evolution in γ-ray bursts has been found using both the GRS and HXRBS experiments on SMM. Results from this study were presented at the Toulouse COSPAR Meeting and will be published in *Advances in Space Research.*

4.0 ATMOSPHERIC GAMMA-RAY SPECTRUM

Additional analysis on the spectrum of atmospheric γ-ray emission has been performed. Preliminary results of this analysis have been presented at the XXVIth COSPAR Meeting and will be published in *Advances in Space Research.* A more detailed paper for submission to JGR is in progress.

5.0 GAMMA-RAY LINE EMISSION FROM SUPERNOVAE AND NOVAE

Searches have begun for γ-ray line emission from galactic novae and from supernovae in other galaxies. The sensitivity level for these searches is significantly better ($\sim 10^{-4}$ γ cm^{-2} s^{-1}) than those obtained with other experiments. To date no compelling evidence has been found for line emission at 1275 keV due to ^{22}Na from neon-rich novae or at 847 keV due to ^{56}Fe from any extragalactic supernova, including the recent one (May 1986) in Centaurus A.

6.0 IMPROVED ANGULAR RESOLUTION USING EARTH OCCULTATION

A new technique is being developed in an attempt to determine the spatial distribution of interstellar ^{26}Al observed by the SMM GRS. This technique utilizes 1-min spectral information and ephemeris data to determine when a specific celestial source is either observable or occulted by the Earth. Systematic variations are being evaluated. It appears that this technique will be able to distinguish a point source from a distribution which follows the galactic CO emission. Utilization of this technique may enable the SMM GRS data to be used in the study of selected discrete sources.

7.0 PRODUCTION PROCESSING OF NASA IPD DATA

NASA/IPD data from April through 1986 October 15 have been processed and screened for flares and bursts in the 0.3 to 0.8 MeV window. Nine cosmic γ-ray bursts have been detected; no solar flares were detected.

SUMMARY LIST OF SMM PUBLICATIONS

1979

Publication

"The Gamma-Ray Spectrometer for the Solar Maximum Mission," J. M. Ryan, E. L. Chupp, D. J. Forrest, M. L. Cherry, I. U. Gleske, E. Rieger, G. Kanbach, K. Pinkau, C. Reppin, G. Share, R. L. Kinzer, W. N. Johnson, J. D. Kurfess. In Proc. 16th International Cosmic Ray Conf., Kyoto, Japan, August 1979, Vol. SP, p. 3-1.

Contributed Paper at Meeting

"The Electronics Systems for the Gamma-Ray Experiment for the Solar Maximum Mission," M. Staples, I. U. Gleske, K. Kubierschky. Paper presented at the IEEE Nuclear Science Symposium, San Francisco, California, 17-19 October 1979.

1980

Publication

"The Gamma-Ray Spectrometer for the Solar Maximum Mission," D. J. Forrest, E. L. Chupp, J. M. Ryan, M. L. Cherry, I. U. Gleske, C. Reppin, K. Pinkau, E. Rieger, G. Kanbach, R. L. Kinzer, G. Share, W. N. Johnson, J. D. Kurfess. Solar Phys. 65, 15 (1980).

Invited Papers at Meetings

"The Gamma-Ray Spectrometer Experiment for the Solar Maximum Mission Satellite," E. L. Chupp, D. J. Forrest, J. M. Ryan, M. L. Cherry, I. U. Gleske, C. Reppin, K. Pinkau, E. Rieger, G. Kanbach, G. H. Share, R. L. Kinzer, W. N. Johnson, J. D. Kurfess. Invited talk for the American Institute of Aeronautics and Astronautics, Pasadena, Ca. 14-16 January 1980.

"Solar Gamma-Ray Line Observations on the SMM Satellite - Preliminary Flux Results," E. L. Chupp, D. J. Forrest, J. M. Ryan, M. L. Cherry, C. Reppin, E. Rieger, K. Pinkau, G. Kanbach, G. H. Share, R. L. Kinzer, J. D. Kurfess, W. N. Johnson. Invited talk for the XXIII Plenary Meeting of COSPAR and Associated Events, Budapest, Hungary, June 1980.

"The SMM Gamma-Ray Spectrometer - Initial Performance and Calibration," E. L. Chupp, D. J. Forrest, J. M. Ryan, M. L. Cherry, C. Reppin, E. Rieger, K. Pinkau, G. Kanbach, G. H.

Share, R. L. Kinzer, J. D. Kurfess, W. N. Johnson. Invited talk for the XXIII Plenary Meeting of COSPAR, Budapest, Hungary, June 1980. Read by Dr. R. Ramaty.

"The Gamma-Ray Burst of 19 April 1980: Solar or Cosmic?," G. H. Share, M. Strickman, R. L. Kinzer, W. N. Johnson, J. O. Kurfess, D. J. Forrest, E. L. Chupp, J. M. Ryan, C. Reppin, E. Rieger, K. Pinkau, G. Kanbach. Invited talk for the Conference on Cosmic Ray Astrophys. and Low-Energy Gamma Ray Astronomy, Univ. of Minnesota, Minneapolis, 3-6 September 1980.

"Gamma-Ray Line and Continuum Emission During the 0312 UT Solar Flare of 1980 June 7," D. J. Forrest, E. L. Chupp, J. M. Ryan, C. Reppin, E. Rieger, K. Pinkau, G. Kanbach, G. H. Share, R. L. Kinzer, M. Strickman. Invited talk for the Conference on Cosmic Ray Astrophys. and Low-Energy Gamma Ray Astronomy, Univ. of Minnesota, Minneapolis, 3-6 September 1980.

"Recent Results with the Gamma-Ray Spectrometer on the Solar Maximum Mission," E. L. Chupp. Invited talk for the Department of Astro-Geophysics, Univ. of Colorado, 13 October 1980.

Contributed Papers at Meetings

"Solar Gamma-Ray Line Observations on the SMM Satellite - Preliminary Flux Results," E. L. Chupp, D. J. Forrest, J. M. Ryan, M. L. Cherry, C. Reppin, E. Rieger, K. Pinkau, G. Kanbach, G. H. Share, R. L. Kinzer, W. M. Johnson, J. D. Kurfess. Bull. Am. Phys. Soc. 25, 58 (1980).

"The SMM Gamma-Ray Spectrometer - Initial Performance and Calibration," D. J. Forrest, E. L. Chupp, J. M. Ryan, M. L. Cherry, C. Reppin, E. Rieger, K. Pinkau, G. Kanbach, G. H. Share, R. L. Kinzer, J. D. Kurfess, W. N. Johnson. Bull. Am. Phys. Soc. 25, 597 (1980).

1981

Publications

"Gamma-Ray Line Observations at 2.223 MeV on the SMM Satellite - The Event of 1980 June 7," E. L. Chupp, D. J. Forrest, J. M. Ryan, C. Reppin, G. Kanbach, E. Rieger, K. Pinkau, G. Share, R. Kinzer, M. Strickman. Astrophys. J. (Letters) 244, L171 (1981).

"Observations with the SMM Gamma-Ray Spectrometer - The Impulsive Solar Flares of 29 March 1980," J. M. Ryan, D. J. Forrest, E. L. Chupp, M. L. Cherry, C. Reppin, E. Rieger, K.

Pinkau, G. Kanbach, G. Share, R. L. Kinzer, M. Strickman. Astrophys. J. (Letters) 244, L175 (1981).

"Evidence for Impulsive Ion Acceleration During the 0312 UT Flare of 1980 June 7," D. J. Forrest, E. L. Chupp, J. M. Ryan, C. Reppin, E. Rieger, G. Kanbach, K. Pinkau, G. H. Share, R. L. Kinzer. 17th Int. Cosmic Ray Conf. 10, 5 (1981).

"Observation of Gamma-Ray Bursts with the SMM Gamma-Ray Spectrometer," G. H. Share, M. Strickman, R. L. Kinzer, E. L. Chupp, D. J. Forrest, J. M. Ryan, E. Rieger, C. Reppin, G. Kanbach. 17th Int. Cosmic Ray Conf. 9, 35 (1981).

"Model Calculations on Fast Solar Neutrons and the 2.2 MeV Line Emission from Solar Flares," G. Kanbach, K. Pinkau, C. Reppin, E. Rieger, E. L. Chupp, D. J. Forrest, J. M. Ryan, G. H. Share, R. L. Kinzer. 17th Int. Cosmic Ray Conf. 10, 9 (1981).

Invited Papers at Meetings

"Gamma-Ray Spectroscopy on the Solar Maximum Mission," E. L. Chupp. Invited talk at the 1981 Spring Meeting of the American Physical Society, Baltimore, Maryland, 20-23 April 1981.

"Gamma-Ray Transients and Related Astrophysical Phenomena," E. L. Chupp. Invited review talk at the Workshop on Gamma Ray Transients and Related Astrophysical Phenomena, University of California - San Diego, 5-8 August 1981.

Contributed Papers at Meetings

"Evidence for Impulsive Ion Acceleration During the 0312 UT Flare of 1980 June 7," D. J. Forrest, E. L. Chupp, J. M. Ryan, C. Reppin, E. Rieger, G. Kanbach, K. Pinkau, G. Share, R. L. Kinzer. Bull. Am. Astron. Soc. 12 No. 4, 890 (1980).

"A Search for Cosmic and Solar Gamma-Ray Lines Using the SMM GRE Detector," J. H. Beall, R. L. Kinzer, G. H. Share, M. S. Strickman, E. L. Chupp, D. J. Forrest, J. M. Ryan, C. Reppin, E. Rieger. Invited talk at the 1981 Spring Meeting of the American Physical Society, Baltimore, Maryland, 20-23 April 1981.

"Neutron, Positron, and 4 to 8 MeV Gamma-Ray Production in Solar Flares," R. Ramaty, B. Kozlovsky, E. L. Chupp, D. J. Forrest. Bull. Am. Astron. Soc. 12 No. 4, 890 (1980).

"Observations with the SMM Gamma-Ray Spectrometer - Time History of the Energetic Photon Emission for 0117 UT Flare on 1980 June 21," C. Reppin, E. Rieger, G. Kanbach, K. Pinkau, D. J. Forrest, E. L. Chupp, J. M. Ryan, G. Share, R. L. Kinzer. Bull. Am. Astron. Soc. 12 No. 4,(1980).

"Observations with the SMM Gamma-Ray Spectrometer - Spectral Features of the Energetic Photon Emission for the 0117 UT Flare on the 1980 June 21," G. H. Share, R. L. Kinzer, D. J. Forrest, E. L. Chupp, J. M. Ryan, E. Rieger, C. Reppin, G. Kanbach, K. Pinkau. Bull. Am. Astron. Soc. 12 No. 4, (1980).

"Observations with the SMM Gamma-Ray Spectrometer - The 'Pokey' Gamma-Ray Solar Flare at 0345 UT on 1980 November 6," J. M. Ryan, E. L. Chupp, D. J. Forrest, C. Reppin, E. Rieger, G. Kanbach, K. Pinkau, G. Share, R. L. Kinzer. Bull. Am. Astron. Soc. 12 No. 4, 891 (1980).

"Evidence for Multiple Neutron Injection During the 10 April 1981 Solar Flare," E. L. Chupp, D. J. Forrest, J. M. Ryan, C. Reppin, E. Rieger, G. Kanbach, K. Pinkau, G. Share, R. Kinzer. American Geophysical Union Spring Meeting, Baltimore, Maryland, 28-29 May 1981.

"Gamma-Ray Observation of the White Light Flare of 1 July 1980," J. M. Ryan, E. L. Chupp, S. M. Matz, E. Rieger, C. Reppin, G. Kanbach, G. H. Share. Bull. Am. Astron. Soc. 13, 902 (1981).

"The Spectrum of Prompt Nuclear Deexcitation Gamma-Ray Lines From Solar Flares," D. J. Forrest, B. M. Gardner, S. M. Matz, E. L. Chupp, C. Reppin, E. Rieger, G. Kanbach, G. H. Share. Bull. Am. Astron. Soc. 13, 903 (1981).

"A Comparison of Gamma-Ray Line and X-Ray Bremsstrahlung Time Profiles in Several Flares," B. M. Gardner, D. J. Forrest, M. C. Zolcinski, E. L. Chupp, E. Rieger, C. Reppin, G. Kanbach, G. H. Share. Bull. Am. Astron. Soc. 13, 903 (1981).

"A Comparison of Gamma-Ray Line and X-Ray Bremsstrahlung Time Profiles in Several Flares," B. M. Gardner, D. J. Forrest, M. C. Zolcinski, E. L. Chupp, E. Rieger, C. Reppin, G. Kanbach, G. H. Share. Bull. Am. Astron. Soc. 13, 903 (1981).

"Heliocentric Angular Dependence for Gamma-Ray Flares Observed with the SMM Satellite," M. C. Zolcinski, D. J. Forrest, B. M. Gardner, E. L. Chupp, C. Reppin, E. Rieger, G. Kanbach, G. H. Share. Bull. Am. Astron. Soc. 13, 903 (1981).

Invited Lectures

"SMM Gamma-Ray Results," E. L. Chupp. Lecture given at the Enrico Fermi Institute, Laboratory for Astrophysics and Space Research, University of Chicago, Chicago, Illinois, 17 June 1981.

"SMM Solar Neutron Results," E. L. Chupp. Lecture given at the Enrico Fermi Institute, Laboratory for Astrophysics and Space Research, University of Chicago, Chicago, Illinois, 24 June 1981.

Invited Lectures Given by E.L. Chupp on SMM Results

Institute for Astronomy, University of Hawaii (August 1981)
Rikkiyo University, Tokyo, Japan (August 1981)
Tokyo Astronomical Observatory, Tokyo, Japan (August 1981)
Nagoya University, Nagoya, Japan (August 1981)
SIRO - Division of Radio Physics, Epping, NSW, Australia (October 1981)
University of Melbourne, Melbourne, Australia (November 1981)
University of Tasmania, Hobart, Tasmania (November 1981)
Sydney University, Sydney, Australia (December 1981)

1982

Publications

"Solar Energetic Photon Transients (50 keV - 100 MeV)," E. L. Chupp. (eds.) R. E. Lingenfelter, H. S. Hudson, D. M. Worrall (New York: AIP), 77, 363 (1982).

"A Direct Observation of Solar Neutrons Following the 0118 UT Flare on 1980 June 21," E. L. Chupp, D. J. Forrest, J. M. Ryan, J. Heslin, C. Reppin, K. Pinkau, G. Kanbach, E. Rieger, G. H. Share. Astrophys. J. (Letters) 263, L95 (1982).

Invited Papers at Meetings

"High-Energy Neutral Radiations from Solar Flares," E. L. Chupp, D. J. Forrest. Invited talk at Solar Physics Division Meeting of the American Astronomical Society, Boulder, Colorado, January 1982 Bull. Am. Astron. Soc. 13, 903 (1982).

"Solar Gamma-Ray Lines: Their Discovery Observations on SMM and Future Promise," E. L. Chupp. Invited talk for the 4 August 1972, Commemorating the 10th Anniversary of the Discovery of Solar Gamma-Ray Lines, Goddard Space Flight Center, Greenbelt, Maryland, 4 April 1982.

"Solar Flare Gamma-Ray Observations," E. L. Chupp. Invited talk at COSPAR Symposium on the Future of Gamma Ray Astronomy, Ottawa, Canada, May 1982.

"Observations of Gamma-Ray Bursts from 10 keV to 9 MeV," G. H. Share, J. D. Kurfess, S. Dee, E. L. Chupp, J. M. Ryan, D. J. Forrest, J. Lanigan, E. Rieger, G. Kanbach, C. Reppin. in Gamma Ray Transient and Related Astrophysical Phenomena, ed. R. E. Lingenfelter, H. S. Hudson, D. M. Worrall, (American Institute of Physics: New York) p. 45 (1981).

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"The Directivity of High Energy Emission from Solar Flares," W. T. Vestrand, D. J. Forrest, E. L. Chupp, G. Share. Paper to be published in the Proceedings of the XXVI Plenary Meeting of COSPAR (1987).

Invited Papers at Meetings

"High-Energy Particle Production in Solar Flares (SEP, Gamma-Ray and Neutron Emissions)," E. L. Chupp. To be published in Physica Scripta (in press) 1987.

Abstracts submitted to 20th International Cosmic Ray Conference

"A Search for Gamma-Ray Line Emission from Novae Using the SMM Gamma-Ray Spectrometer," E. L. Chupp, W. T. Vestrand, D. J. Forrest.

"Mercury 2000: Stereoscopic Observations of Gamma Ray Flares," J. F. Cooper, A. E. Metzger, E. L. Chupp.

"A Search for Gamma-Ray Lines from Nucleosynthesis Products of Supernovae," S. M. Matz, G. H. Share, W. R. Purcell, R. L. Kinzer, E. L. Chupp, D. J. Forrest.

"Gamma Rays from Supernovae," W. T. Vestrand, E. L. Chupp, D. J. Forrest.

"Simulations of Stereoscopic Solar Flare Observations," W. T. Vestrand, A. Ghosh.